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Study of the potential impact of Quality-of-Experience based services on Net Neutrality principles

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Title:

**Study of the potential impact of Quality-of-Experience based
services on Net Neutrality principles**

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1. Introduction

The rapid growth in mobile networks traffic mainly generated by the popularity of multimedia content poses new challenges for network operators. While in 1G and 2G networks mobile traffic was mainly voice, with 3G and 4G networks development traffic is now dominated by video and data owing to applications like video streaming, Facebook, Twitter and mobile browsing. This has not only increased the amount of mobile broadband traffic transported by the carrier networks, but also transformed its composition. Indeed, mobile video will generate much of the mobile traffic growth through 2018 (at a CAGR of 69% between 2013 and 2018), indicating the highest growth rate of any mobile application (Ericsson, 2013). We have moved from a world where providing quality speech was the major concern to one where we must incorporate techniques to manage diverse traffic characteristics of the growing range of multimedia applications and services. At the same time, the demand for enhanced user's experience with differentiated service levels also extends. This trend continues to growth as the variety and number of applications and services increases, and the subscriber base grows. To succeed in this competitive landscape, operators are required to choose a more rigorous approach, reducing the network's operational expenditure while dealing with the increasing quality demands of the users (Markendahl, 2009; Yin and Liu, 2000; Aristomenopoulos, 2010).

In this scenario, operators have the opportunity to lead the market on service differentiation by delivering the appropriate user's QoE with the speed, capacity, coverage and availability demanded by users of laptops, smartphones and other devices. However, the implementation of QoE-based differentiation at the service provision, with the potential deployment of fast lanes for premium users, the prioritization of traffic, or the creation of user's categories, could affect the Net Neutrality principles that claim Internet service providers must not speed up, slow down or block Internet traffic based on its source, ownership, type or destination. In this context, it is important to understand how the interest of operators, content providers and users can fit with the concept of network neutrality, fairness and freedom of expression, while satisfying commercial demands, business models and personal interests.

Internet broadband access is a two-sided business (Economides, 2009) where the network owner needs to provide connectivity access to the end users, which want to access contents on Internet. In this context, the relations between Content Service Providers, Internet Service Providers, regulator and Internet users should be the focus for innovation and regulation in order to assure Net Neutrality.

The proposed paper will focus its results on the analysis of how the net neutrality principles will impact the implementation of QoE-based differentiation in the service

provision. Our intention is to evaluate the effect of this approach for the different actors involved in the mobile ecosystem (i.e., content provider, network provider, vendor, regulator and users).

Here goes the chapter organization. Section 2 presents the evolution of the QoE concept. In section 3 the QoE ecosystem is introduced. Then, a description of the Net Neutrality concept and the relevant discussion points in the topic is introduced in section 4. An initial discussion about the impact of Net Neutrality on QoE is presented in section 5. Finally, the conclusions section is presented.

2. Evolution of the Quality of Experience (QoE) concept.

From providers' perspectives, the interpretations of QoE go hand-in-hand with the assumption that by optimizing the Quality of Service (QoS), the end user's QoE will also increase. However, this is not always the case. Even though, QoS implementation enables network operators to isolate traffic into flows based on attributes, such as traffic type (voice, video or control) or application needs (throughput, latency and/or jitter), this focus does not consider all the content delivered features or the use of information regarding the content processing, provided by terminals.

The concept of QoS continues to be important in the service provider environment, but QoE is rapidly gaining mindshare. The QoE concept differs from QoS in that it considers much more than the network performance. QoE is concerned with the overall experience consumers have when accessing and using provided services. Thus, it is important for operators and content providers to incorporate a high degree of intelligence to transport different types of traffic in a way that provides a satisfactory and competitive end-user experience, while also maximizing revenue per user. With the development of mobile networks, customer needs and behaviors have changed. Mobile communications means so much more than simple voice communication; there is now mobile Internet with web surfing, video phone, streaming media, and microblogging. Traditional KPIs are no longer adequate for measuring the quality of mobile services. The objective of network optimization has gradually shifted from enhancing network performance to improving QoE. This makes QoE a new fundamental component of the mobile networks framework for satisfactory delivery of applications and services with effective end-to-end management of network resources.

The main challenge that operators face nowadays is to find a solution to manage the traffic growth while meeting the users' expectations in a cost effective manner. A common approach to reach the goal of high quality information delivery has been the implementation of resource management schemes and scheduling algorithms to optimize resource allocation and traffic distribution as function of network parameters (Yin, 2000) (Piamrat, 2009) (Thakolsri, 2009) (Aristomenopoulos, 2010) (Shehada, 2011)

(Chuah, 2012) (Dutta, 2012). By maximizing performance through infrastructure improvements mostly oriented to increase QoS, network providers want to meet the growing end-user demand for more quality and faster connectivity on the move.

Solutions have been gradually evolved from a perspective mainly centered on the evaluation of network based constraints (e.g. signal-to-noise ratio (SNR) or instant data rates) deprived of knowledge about the transferred content (Yin 2000), to a perspective where inherent characteristics of the content are considered to improve network performance. In this regard, solutions oriented to improve video transmission are a clear example. Although proposed solutions offer a path towards the solution of the traffic growth and the demanding user expectation issue, this approach does not consider the type of content delivered by the network or the use of information provided by terminals to manage the resource allocation.

In that sense, it is also important to consider what is happening during the content processing at user's side in order to get a better picture of the traffic management. Mobile networks can utilize this information to impact in a positive way the use of limited resources inside the infrastructure. It is possible to incorporate and provide awareness to the wireless infrastructures in the context of cross-layer systems to manage the resource allocation according to expected QoE levels. From a user's perspective, this QoE-awareness will represent the probability that the network delivers sufficient performance to run a particular application/service at an acceptable quality level. From the network side, the use of this concept would ensure a high probability that the most widely used application/services will deliver exactly what the user expects, improving the utilization of the network infrastructure resources.

3. QoE Ecosystem

QoE is an assessment of the human experience when interacting with technology and business entities in a particular context. In that sense, an analysis of the QoE ecosystem should consider different players interacting with each other at different levels (technical, social, business) and with different approaches. For understanding the structure of the QoE ecosystem it is important to define/identify a framework that describes the main interactions between users, business, and technology in a communication service provision. This is illustrated in Figure 1.

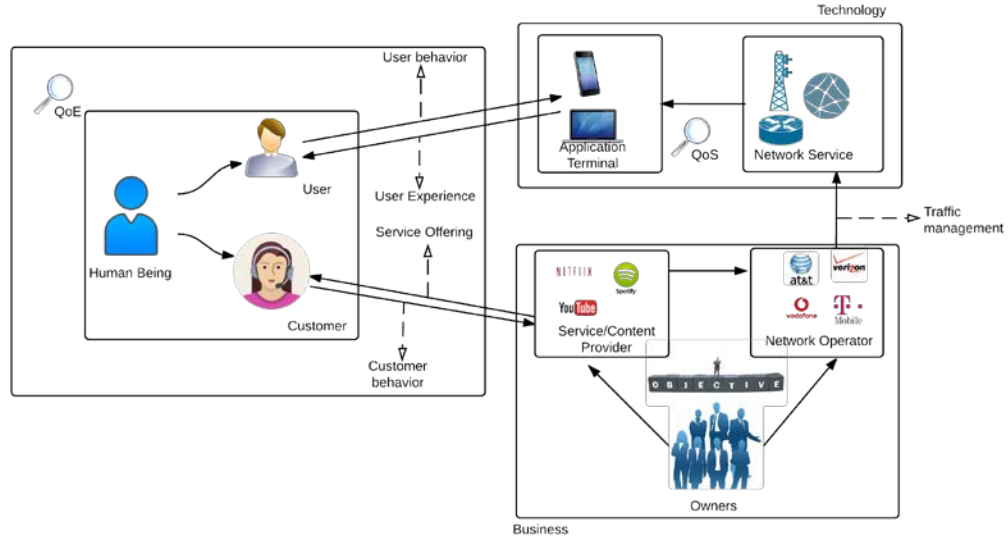


Figure 1. Mobile business ecosystem.

The framework includes two actors that have independent aims: customers who want to maximize their happiness, and content and network providers who want to maximize their income. Services are offered and networks are built only if service providers have opportunity for profitable business and customers have possibility to obtain real benefits. On the other hand, any commercial company shall make their operational decisions based on clear business objectives. A typical objective is to maximize Return of Investment (ROI).

In the proposed framework it is also possible to identify different interactions. For instance, content, services and network providers try to provide a better user experience by ensuring network and service performance based on QoS models. From a business side, these actors need to develop economic models and business models for their technological infrastructure. This business interaction also implies an identification of how effectively the operators can utilize their resources to increase their profit by retaining customer as well as attracting new ones. The interaction between user and providers develops customer experience models to understand customer requirements with respect to business aspects. Customer care, cost, promotion and brand image may influence customers to develop positive or negative feelings about a service. Therefore, one could say the QoE of a service is influenced by three major dimensions: the content provider requirements with respect to QoS, the actual QoS that is delivered by the network and the user preferences and expectations about the service experience, including the contextual factors that can influence users' perceptions.

The Internet is rapidly evolving, with services demanding ever higher levels of network capacities. This has led to the exploration of alternative ways the access internet service providers can monetize on their position as gatekeepers, in order to finance the high levels of investments. In general what is being explored is the transition from a neutral network to a non-neutral network where the internet service providers can differentiate and prioritize content, and much research has been done to analyze the effects of such a transition.

4. Net Neutrality

Net Neutrality literature has become a quite extensive research field after its appearance in early 2000s, after initial calls from advocates, independent ISPs and academics related to open cable access in the US. (Lessig, 2001; Speta, 2000; Wu, 2003; Yoo, 2004). The initial research has been mainly conducted in the fields of law and economics, analyzing the different economic and market issues related to Net Neutrality. A common concept used in Net Neutrality is the public interest paradigm, where it is assumed that regulation will protect consumers from market failures such as monopoly (Baldwin, Cave, and Lodge, 2012; Carpenter, 2010; Posner, 1974; Trebing, 1981; Viscusi, Harrington, and Vernon, 2005) This is also an ideological debate that have arisen in many sectors of society, whether regulation is an efficient tool and what are its strengths and weaknesses. The key aspect in which Net Neutrality literature has focused is whether the ISPs have or not economic incentives to discriminate traffic, and how consumers and the economy will suffer from such behavior. Going in more detail, circumstances like regulatory intervention, monopoly situation and the effects of market power are central in the discussion.

On the other hand, regulators have so far responded differently towards Net Neutrality. The Federal Communications Commission (FCC) has rules oriented to preserve the Internet's openness and broadband providers' ability to manage and expand their networks". These rules are supported on four principles: transparency, no blocking of content, no unreasonable discrimination, and reasonable network management. Meanwhile, the European Commission believes that the existing rules on transparency, consumer switching and quality of service are sufficient to ensure competitive outcomes (Nurski, 2012). However, the EU has recently stated that the Internet could be split in two, internet access services (IAS) and specialized services (SS). Internet access services should be open without traffic management. With specialized services operators may offer QoE for the end-user and manage the networks how they want. However, the splitting point between these two networks has not yet been decided (BEREC, 2012).

Finally, we can see Net Neutrality literature offers studies on the potential behavior of ISPs inducted from economic and business theory and observation from economic constraints. Commonly, scholars have offered recommendations on regulation but quite few attempted to explain why they do what they do. (<https://www.alissacooper.com/phd-thesis/>). One key concept to keep in mind is Institutionalism, which refers to the idea that “institutions matter” in shaping human behavior and decision-making. (Baldwin, Cave, and Lodge, 2012; Black, 1997). Researchers on regulatory activity and behavior theory have explored how formal institutions affect market outcomes. Based on this general introduction we have based our literature review in two main blocs: Technical and Economic arguments on the Net Neutrality debate. Within the Economic arguments we will make a differentiation between Economic rationales for discrimination, Incentives in Market power situations and Effects of Competition on Incentives to discriminate. (<https://www.alissacooper.com/phd-thesis/>)

4.1. Technical arguments

The basic argument in favor of Net Neutrality regulation starts with the idea of the technical principles articulated about the Internet’s early architecture. From this perspective, Internet’s technical design based on the “best effort” principle has provided for an unmatched platform enabling flourish of new applications in the edges. Legal research has asserted that the nature of non-discrimination on the Internet was already introduced in the nature of its technical architecture, and that ISPs potentially treating traffic differently would be against this end-to-end design. (Frischmann and van Schewick, 2007; Lessig, 2001; Lemley and Lessig, 2001; van Schewick, 2010; Wu, 2003).

The main strength of Internet’s design is that it enables innovation on the edges with great speed and low barriers of entry, which creates a very good competitive environment. Traffic discrimination could potentially end-up this environment by turning ISPs into gatekeepers, with decision power on which applications succeed or fail. (Lennett, 2009). A contrary line of thinking states that traffic discrimination improves network by allowing ISPs to discriminate traffic with specific needs, making communication services more valuable to consumers. In addition to that, some scholars state that traffic management not only increases performance but it is also essential to efficient operation of broadband networks. (Crocioni, 2011; Hazlett and Wright, 2011; Prüfer and Jahn, 2007; Renda, 2008; Singer, 2007).

From performance point of view, prioritization schemes are mostly useful when networks are experiencing congestion. Therefore, those against discrimination argue that the best solution for congestion is expanding capacity. Changing network usage patterns that create performance problems may be one key driver for discriminatory traffic

management. (Lennett, 2009; Lessig, 2006; Odlyzko, 2009), (Faulhaber and Farber, 2010). However, theoretical economic literature also states that traffic discrimination may lead into bandwidth inefficiency. The model from Economides and Hermalin shows that discrimination increases demand on high priority services leading to re-congestion in this lane. (Krämer and Wiewiorra, 2013; Wiewiorra, 2012) (Economides and Hermalin, 2012).

4.2. Economic arguments

Technical arguments are relevant and needed to be taken into account, however ISPs decisions are mainly seeking increasing benefit. ISPs must justify their decisions in front of the stakeholders based on economic arguments and there are some researches that can provide insights on the economic rationales behind traffic discrimination. Economic literature on Net Neutrality has focused on how traffic management can make broadband services more valuable to final users and thereby increase subscription fees. Researchers have found that discrimination can enable a new market in which broadband offerings can better suit consumer demands. These observations rely on the basic idea that differential pricing has the potential to enhance user experience and value perceived. (Weisman, 2010; Yoo, 2004)

Discrimination is also considered to reduce costs, since ISPs pay interconnection fees based on the amount of traffic exchanged therefore we can find an incentive to reduce high volume applications via extra-fees. (Marsden, 2010; van Schewick, 2010). From a welfare perspective, researchers defend the fact that discriminatory management creates the potential bandwidth to provide better services for all users. From the economic perspective, operators are nowadays constraint into offered flat rates and single price but by introducing traffic discrimination they would be able to charge based on specific type of consumption, which potentially could increase their benefit. (Levinson and Odlyzko, 2008). In the background of these reasoning lays the concept of a “two-sided market”, in which ISPs are in the middle charging and having relationships with both final users and content providers. This well-known market model has been studied in deep in literature. (Economides and Tag, 2012)

Incentives in market power situations

The idea that ISPs with Market Power situations may be willing to leverage its dominance is something familiar in the telecommunications sector. A dominant player in the telecommunications sector may have the incentive to exploit and control its network in order to foreclose competition reducing service options to consumers. (Nuechterlein and Weiser, 2005) This can be done by simply raising prices or reducing the quality of independent applications, actions that will lead to market monopoly. This is the main concern of those who advocate in favor of Net Neutrality regulation, which in a situation

of lack of competition ISPs would act on these incentives to discriminate. (Atkinson and Weiser, 2006). However, this idea that market monopoly may lead to traffic discrimination is not held by everybody and there are scholars defending that there is not a cause-effect relation.

Another important aspect to bear in mind is the network effect, the fact that the more users internet has the more value it has as a platform. As a consequence of this network effects, ISPs would be against limiting the usage of the internet in order to avoid reducing the value of the platform itself. Finally, the Internet is the ultimate communication platform that services a number of services and functions but, at the same time, increases current productivity and helps development of non-internet services. In this line, many scholars have highlighted the importance of internet in terms of its beneficial impact on society. (Lemley and Lessig, 2001; Lennett, 2009; Lessig, 2006; van Schewick, 2007; Werbach, 2005; Whitt, 2004; Wu, 2003; Wu, 2004; Wu and Lessig, 2003; Hogendorn, 2012 and van Schewick, 2010).

Effects of competition on Incentives to Discriminate

A big part of Net Neutrality literature discuss over on whether competition can detain ISPs from traffic discrimination. Competition among ISPs is said to avoid independent service providers from being foreclosed from the market. In a broadly approach, competition generally reduces the ISPs incentives to traffic discrimination because discrimination causes loss of broadband users. The big question here is to which extent can competition reduce the incentives to discrimination and if it is enough or regulation is needed. This question remains unclear, and may be central for future research on the topic. (Crawford, 2007; Herman, 2006; Jordan, 2007; Lemley and Lessig, 2001; Lessig, 2001). Defenders of competition as a sufficient tool to avoid discrimination, also identify that the bigger problem is the lack of competition in some broadband markets, such as the U.S. In addition to this line of thinking there are scholars stating that intense competition is not a sufficient tool in order to prevent discrimination. Technical incentives remain relevant and ISPs could potentially use discrimination to enhance their own services.

Finally, the ones considered about stopping innovation state that competition based only on customer preferences is not enough as closure to create a cost of innovation that it is not reflected in consumers purchasing decisions. (Lemley and Lessig, 2001)

5. Discussion Net Neutrality and QoE

Quality of service (QoS) parameters and mechanisms are important to enable network operators to design, build and manage their networks, but they are not directly visible to end-users. Crucial for the end-users, however is the quality that they personally

experience when they use a service. QoS involves tracking of jitter, latency and other measurable parameters. If the QoS score is not good enough, operators can identify the problem and fix it. With QoE the solution is less straight-forward. QoE is a subjective measure of how the viewer is judging the content delivered by the network. This means the same type of content might be evaluated in a different way depending on the user profile and expectations.

Meeting user expectations would require from the content provider and the network operator a deeper understanding of the user interests, awareness of the content that is traversing the network, and new ways to manage/prioritize the traffic. The analysis of the understanding of users' interests requires behavioral analysis that is out of the scope of this paper, so we focus our analysis in the technical details of network awareness and traffic management. In these two cases, one of the key tools to provide awareness and activate traffic management policies is deep packet inspection (DPI). DPI, as the name implies, is a technique that digs into a packet to determine precisely what it is delivering and how various elements measure up against a predetermined norm. It is a potent technology. The idea is that such granular assessments be combined with machine intelligence and big data analytics will produce a tremendous amount of data that will help to improve QoE in a number of ways. The first, of course, is simply to improve audio and video. Beyond that, the placement of sensors in the field and their assessment of QoE at strategic points can help in root cause analysis of problems, aid in the planning of system upgrades and even support sales efforts. However, it remains to be seen how deeply it can be leveraged by operators. The uncertainty about Net Neutrality is causing some operators to move a bit more slowly on QoE in general and DPI in particular.

Traffic management is a collection of technologies and policies which lead to different types of traffic being treated differently, which in principle goes beyond the best effort principles that support the original Internet idea. Without traffic management, different data packets are treated more or less equally, which means that under congested conditions traffic management would cause some data to have a greater chance of being delivered than others. Traffic management can be implemented in different ways, which include:

- guaranteeing delivery of data or reserving bandwidth for that data;
- prioritizing certain types of data in the event of queuing;
- de-prioritizing certain types of data;
- restricting certain types of data or the bandwidth allocated;
- blocking certain types of data.

Such discrimination between data types would probably affect users' QoE; in the extreme some applications would not be able to function. Of course, congestion could also cause applications to fail, but the distinguishing feature of traffic management is that it involves purposeful discrimination. In one hand, the traffic management could guarantee or prioritize data for sensitive applications and reduce the congestion to manageable levels, allowing fair use for all the users, increasing their satisfaction levels. On the other hand, the traffic management can restrict or block certain applications and make other people's traffic take priority, which can generate a negative impact on the user's perception.

However, it is important to consider that at an individual connection or device, a user cannot necessarily observe traffic management directly. The amount of traffic management and its effects on users can differ according to the level of congestion on the network. Both the amount of traffic management and its impact depend on the level of traffic at the time. User can observe the performance of an application and decide whether the performance is acceptable or not. If the application works as expected, he or she can infer that the data have arrived in a timely manner. But it is impossible to tell whether the data have arrived only because they have been prioritized, or whether they have arrived because best efforts are perfectly adequate. Full transparency would involve providing data that describe the effects of policies over time and therefore the resulting quality of experience for users. This implies the need for diagnostic tools to help users understand whether and in what way traffic management is affecting them.

6. Conclusions

In this paper we have introduced an initial analysis of how the net neutrality principles will impact the implementation of QoE-based differentiation in the service provision. In our study we focus on the analysis of the evolution of QoE concept and how the elements associated to QoE gain more importance in the telecommunications market. Then, we introduce the concept of Net Neutrality, where one of the main discussion points is whether the ISPs have or not economic incentives to discriminate traffic, and how consumers and the economy will suffer from such behavior. Going in more detail, circumstances like regulatory intervention, monopoly situation and the effects of market power are central in the discussion.

Finally, we could see that Net Neutrality may influence QoE in two ways: how deeply operators are allowed to examine the packets flowing through those networks in order to use the extracted information to feed mechanisms to improve users' QoE, and the transparency about the prioritization policies implemented to fulfill user' expectations and requirements.

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